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BRAZE ALLOY INVESTIGATION
NASA CONTRACT NO. NAS1-6666
HYPERSONIC RESEARCH ENGINE PROJECT - PHASE IIA

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ABSTRACT

A new braze alloy, designated Palniro RE, was developed especially for use on the Hypersonic Research Engine. The braze alloy composition is 55 w/o Gold-30 w/o Nickel-15 w/o Palladium, and it has a nominal braze temperature of 2025 degrees F. The evaluation of this braze alloy provided data on melting temperature, wettability and filleting, alloying and intergranular penetration with Palniro 1; remelt and diffusion with Palniro 1 and Palniro 4, and creep rupture strength when used for brazing of plate-fin flat panels. In addition, an evaluation was made of the creep rupture strength of Palniro 1. The creep rupture tests show the Palniro RE to be weaker than Palniro 1 or Palniro 4. Palniro RE is not suitable for use in brazing plate-fin shells that operate at the highest engine temperature; however, it is suitable for use in brazing the manifolds to the shell structures.

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1.0 FLAT PANEL RUPTURE AND BRAZE ALLOY EVALUATION

1.1 PALNIRO RE BRAZE ALLOY EVALUATION

1.1.1 Introduction

The need has been apparent for an additional braze alloy for use on the HRE structure in brazing subassemblies and in intermediate brazing operations involved in assembling the structures.

1.1.2 Test Procedure

A modification of the gold-nickel-palladium series of alloys was offered for evaluation by Western Gold and Platinum, designated Palniro RE, with a composition of 55 W/O Gold - 30 W/O Nickel - 15 W/O Palladium, and nominal braze temperature of 2025°F. A supply of the alloy in the form of 0.001 in. thick foil and of powder (325 mesh) was procured and evaluated both from the standpoint of its brazing characteristics and its strength at high temperature when used in fin-skin joints of a flat test panel.

To determine the brazing characteristics of the alloy, a series of small samples was brazed to determine the actual melting range, the wettability, and the filleting capability of the alloy. Samples were prepared and examined metallographically to measure alloying and intergranular penetration. Finally, a series of specimens was prepared by first making joints of Palniro 4 and Palniro 1 alloy, then re-brazing with Palniro RE on the higher melting point alloys.

1.1.3 Results

1.1.3.1 Melting Temperature

The solidus and liquidus temperatures were determined visually to be 1980°F and 2000°F respectively.

1.1.3.2 Wettability and Filleting

The ability of the alloy to wet and fillet the length of a T-joint from a small preplaced supply at one end was determined to be excellent. The Hastelloy X specimens were brazed in a vacuum furnace at 2025°F.



1.1.3.3 Alloying and Intergranular Penetration

The T-joint specimens used for determination of wettability and those used in evaluation of interalloying with Palniro I were sectioned for measurement of alloying and intergranular penetration. Less than 0.001 in. alloying and penetration was measured, as shown by Figure 1.

1.1.3.4 Remelt and Diffusion

Specimens of T-joints were brazed with Palniro 4 (2170°F) and Palniro I (2070°F). Then a tab was attached to the specimen at right angles with the original joint. Finally a supply of Palniro RE was placed on the braze fillet on the side opposite the tab and the specimen was cycled at 2025°F, the brazing temperature for Palniro RE. Examination of the specimens after this cycle indicated that remelt of the Palniro I and/or migration of Palniro RE had taken place. There was no interaction with Palniro 4. The results of this determination indicate that Palniro I cannot be depended upon as a barrier to Palniro RE flow during step brazing operations whereas Palniro 4 does present a barrier to the Palniro RE flow.

1.2 PALNIRO RE CREEP RUPTURE STRENGTH EVALUATION

1.2.1 Introduction

Test data were obtained for three flat panel specimens for creep rupture testing. These panels were the same type as used previously, i.e., two-by-three in. flat panels, with 28R-0.050-0.100-0.006 fins. They are identified as SK51268-8 (S/N 7, 8, and 9). These tests were conducted to obtain comparisons with the elevated temperature strengths of Palniro 4 and Palniro I.

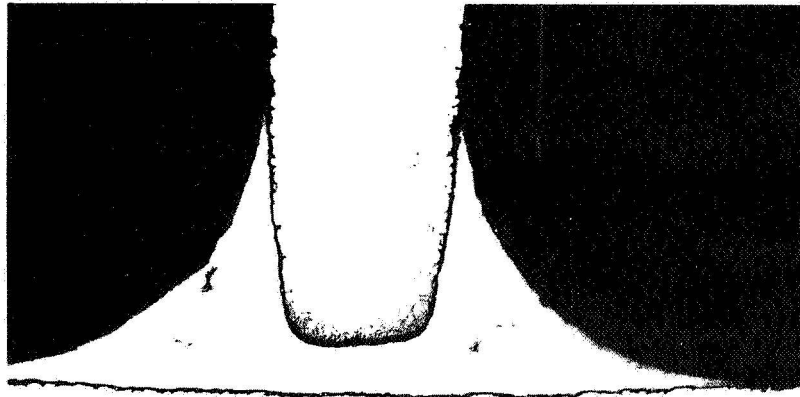
1.2.2 Test Procedures and Results

Table I summarizes the test data and test results. The first two tests were performed at a temperature of 1600°F. When the somewhat lower strengths than those achieved with Palniro 4 and Palniro I were observed, the third specimen was tested by increasing the pressure in increments according to the discrete time intervals noted in Table I. The fin-strength efficiency shown in the table for the third specimen has been computed on the basis of the indicated pressure-time history.

Test Data Reduction

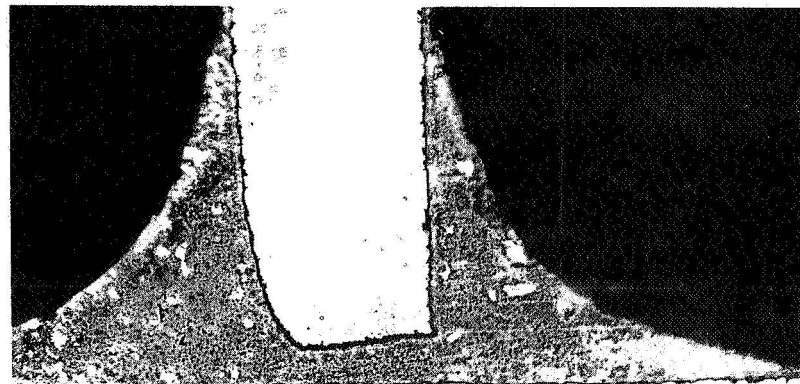
The nominal fin stresses (σ_{nom}) were computed on the basis of an assumed fin strength efficiency of 1.0. The published (σ_{theor}) creep rupture stresses were used for S/N 7 and S/N 8 based upon the elapsed time to creep rupture. The fin-strength efficiency for these specimens was then computed as the ratio between nominal fin stress and published creep rupture stress. These values were 0.254 for S/N 7 and 0.259 for S/N 8.





a. Palniro I Brazed at 2070°F in Vacuum.
MAG 75X

PHOTO 1315



b. Palniro RE Brazed at 2025°F in Vacuum.
MAG 75X

PHOTO 1316

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Figure 1. Photomicrographs of Hastelloy X T-joints Brazed With Palniro I and Palniro RE at Area of Brazing Alloy Placement. Excellent Filleting, Wetting, and Flow Was Obtained With Less Than 0.001 in. Combined Alloying and Intergranular Penetration. Etched With Kalling's Reagent.



TABLE I
PALNIRO RE CREEP RUPTURE TEST RESULTS

S/N	Temperature, °F	Test Pressure, psi	Calculated Fin Stress at Pressure for $f = 1.0$	Time, hr	σ_{theor}	Fin Strength Efficiency, f
7	1600	1000	4950	2.75	19,500	0.254
8	1600	800	3960	8.75	15,300	0.259
		800	3960	51.3	16,800	
		1000	4950	10.0	20,800	
9	1400	1200	6180	10.0	26,000	0.238
		1500	7420	3.1	31,200	



The approach was somewhat modified to obtain the strength performance for S/N 9. The basic premise used to obtain this number was that the fin-strength efficiency during each segment of the test was identical. An estimated fin-strength efficiency of 0.30 was used to obtain theoretical fin stresses during each portion of the test. The theoretical number of hours-to-failure was then obtained for each portion of the test from published data at 1400°F. The life-damage fraction for each test segment was then computed to be the test time divided by the theoretical failure time. These damage fractions were summed up, and the total damage fraction was computed to be 0.233. The procedure was repeated for assumed fin-strength efficiencies of 0.25 and 0.225, and the corresponding damage fractions were found to be 0.721 and 1.401 respectively. The damage fractions were then plotted versus fin strength efficiencies on log-log paper and produced a straight line relationship. The fin-strength efficiency of 0.238 was obtained for a life-damage fraction of 1.0, which was the desired result. This procedure can be applied to any creep rupture test that is performed at more than one load-time segment. In essence, it is based upon the hypothesis that failure occurs when the summation of the life damage fractions is equal to 1.0, and that the strength efficiency is the same during each test segment.

1.3 PALNIRO I CREEP RUPTURE STRENGTH EVALUATION

1.3.1 Introduction

Six 2 by 3 in. flat panel plate and fin test specimens were fabricated and creep rupture tested to obtain comparisons with Palniro 4. Three specimens, SK51268-6, utilized 20R-0-050-0.100-0.006 Hastelloy X fins and three specimens, SK51268-8, incorporated 28R-0.050-0.100-0.006 Hastelloy X fins.

1.3.2 Test Procedures and Results

All tests were conducted at 1600°F. A tabulation of these results and applied pressures is presented in Table 2. An average fin strength efficiency of 41.8 percent was attained with the 20R fins compared to 42.3 percent for Palniro 4, and an average fin strength efficiency attained with the 28R fins was 33.2 percent compared to 37 percent for Palniro 4.

1.4 CONCLUSIONS

The Palniro I braze alloy offers creep strength properties that are virtually the same as those obtained with Palniro 4. For fin pressure containment Palniro I may be used in place of Palniro 4. The reduction in fin-strength efficiency in going from 20R to 28R fins indicates that the limiting factor in overall strength transfers from the fin itself to the brazed fin joint strength. However, there is still an improvement in pressure capability of more than 20 percent in going from 20R to 28R fins.

The tests carried out indicated Palniro RE to be weaker than Palniro I or Palniro 4. This appears to be essentially due to a decrease in joint strength. The braze alloy is not suitable for usage in brazing fins for critical pressure containment areas that operate at elevated temperatures. The main area of application for this alloy will be for joining manifold



TABLE 2
PALNIRO I CREEP RUPTURE TEST RESULTS

Part Number	S/N	Test Pressure psi	Calculated Fin Stress at Pressure for $f = 1.0$	Time, hr	σ theor	Fin Strength Efficiency, f
SK51268-6	9	800	5850	11.6	14,400	0.406
	10	800	5850	12.0	14,200	0.413
	11	800	5850	15.6	13,700	0.433
SK51268-8	5	1000	4950	11.3	14,600	0.339
	6	1000	4950	8.8	15,200	0.327
	7	1000	4950	9.3	15,000	0.330



structures to the structural shells. Metal temperatures in these locations will be less than 1200°F, for which the creep rupture failure becomes less important than the short-time capability. Since the short-time strength efficiencies have generally been 50 to 100 percent larger than the creep strength efficiencies, the short-time strength efficiency with Palniro RE should exceed 40 percent. Since this is greater than the 33 percent strength efficiency number that has been used to determine all margins of safety, the alloy will be acceptable for manifold braze joints.

